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Tang et al.

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(54) **POSITIVE AND NEGATIVE VOLTAGE LEVEL SHIFTER CIRCUIT**

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(60) Provisional application No. 60/980,017, filed on Oct. 15, 2007.

(51) **Int. Cl.**
G11C 7/00 (2006.01)

(52) **U.S. Cl.** **365/189.11; 365/189.12; 365/189.07**

(58) **Field of Classification Search** **365/189.11, 365/189.12, 189.07, 191, 189.05, 189.03, 365/189.08**

See application file for complete search history.

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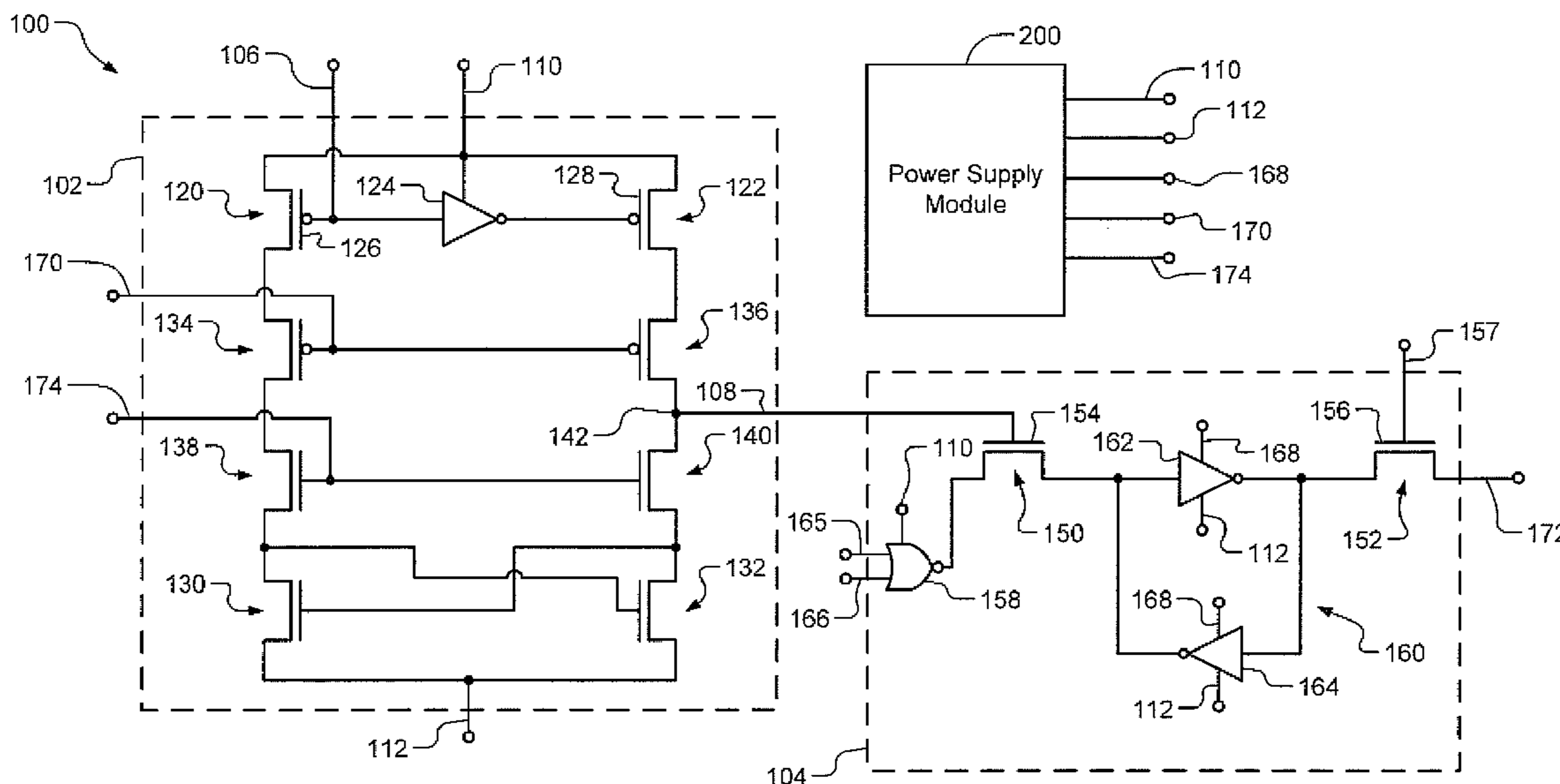
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Primary Examiner — Dang Nguyen

(57) **ABSTRACT**

A level shifter including a level shifter module configured to i) receive an input signal, wherein the input signal varies between a first level and a second level, ii) receive a first voltage supply signal and a second voltage supply signal, and iii) generate a latch control signal based on the input signal and one of the first voltage supply signal and the second voltage supply signal. The level shifter further includes a latch module configured to i) receive the latch control signal, ii) receive the second voltage supply signal and a third voltage supply signal, and iii) generate an output signal based on the latch control signal and one of the second voltage supply signal and the third voltage supply signal.

16 Claims, 12 Drawing Sheets



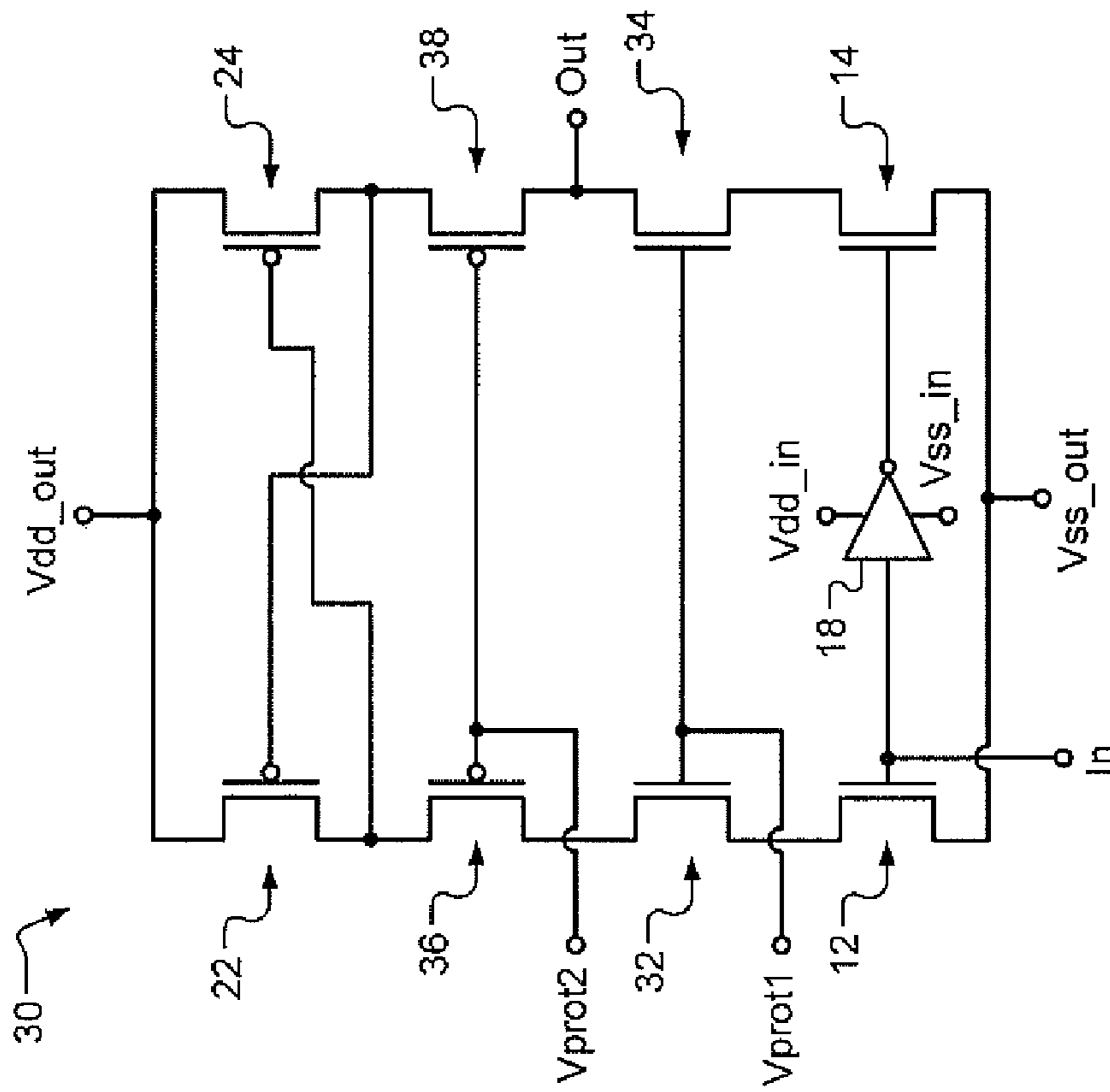


FIG. 1
(Prior Art)

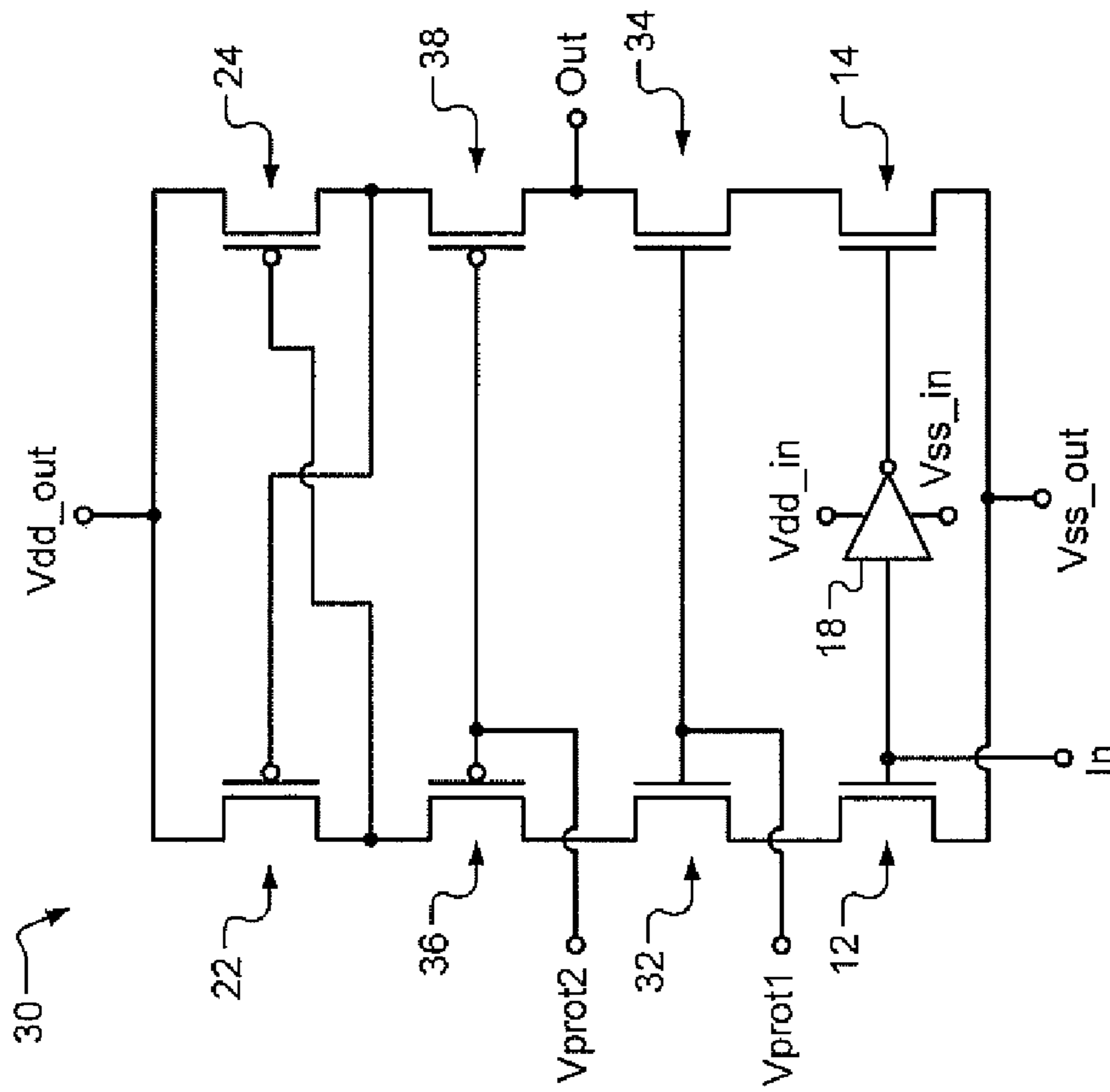


FIG. 2
(Prior Art)

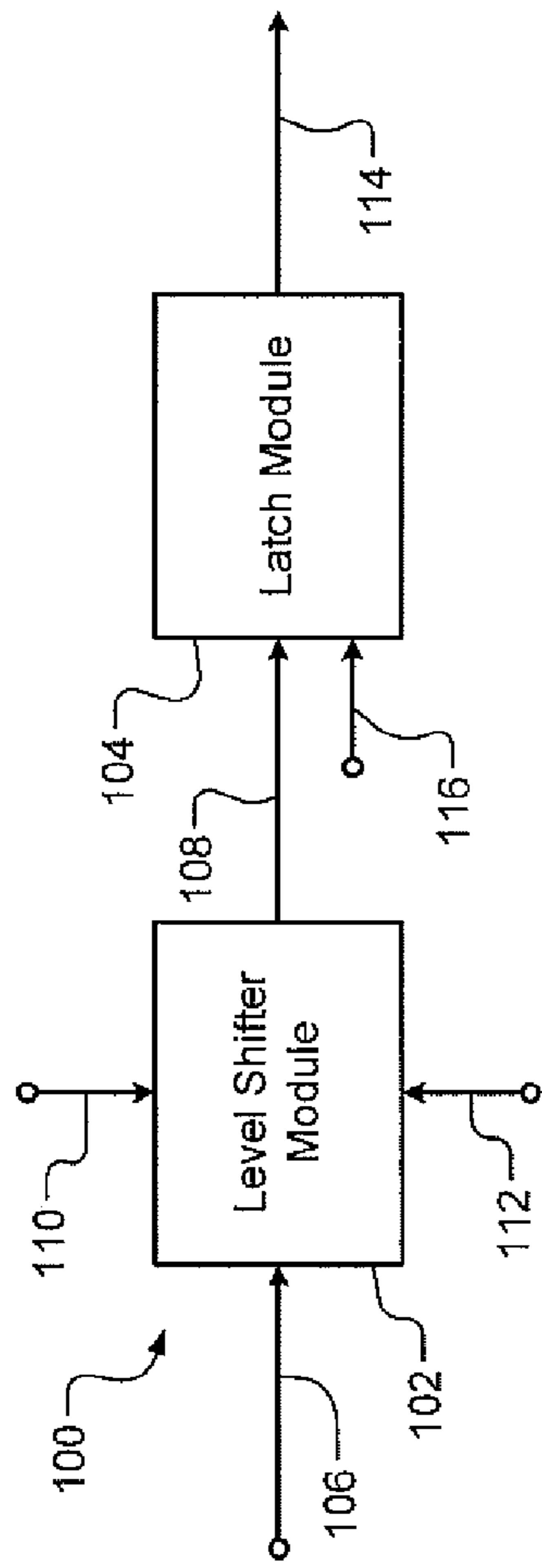


FIG. 3

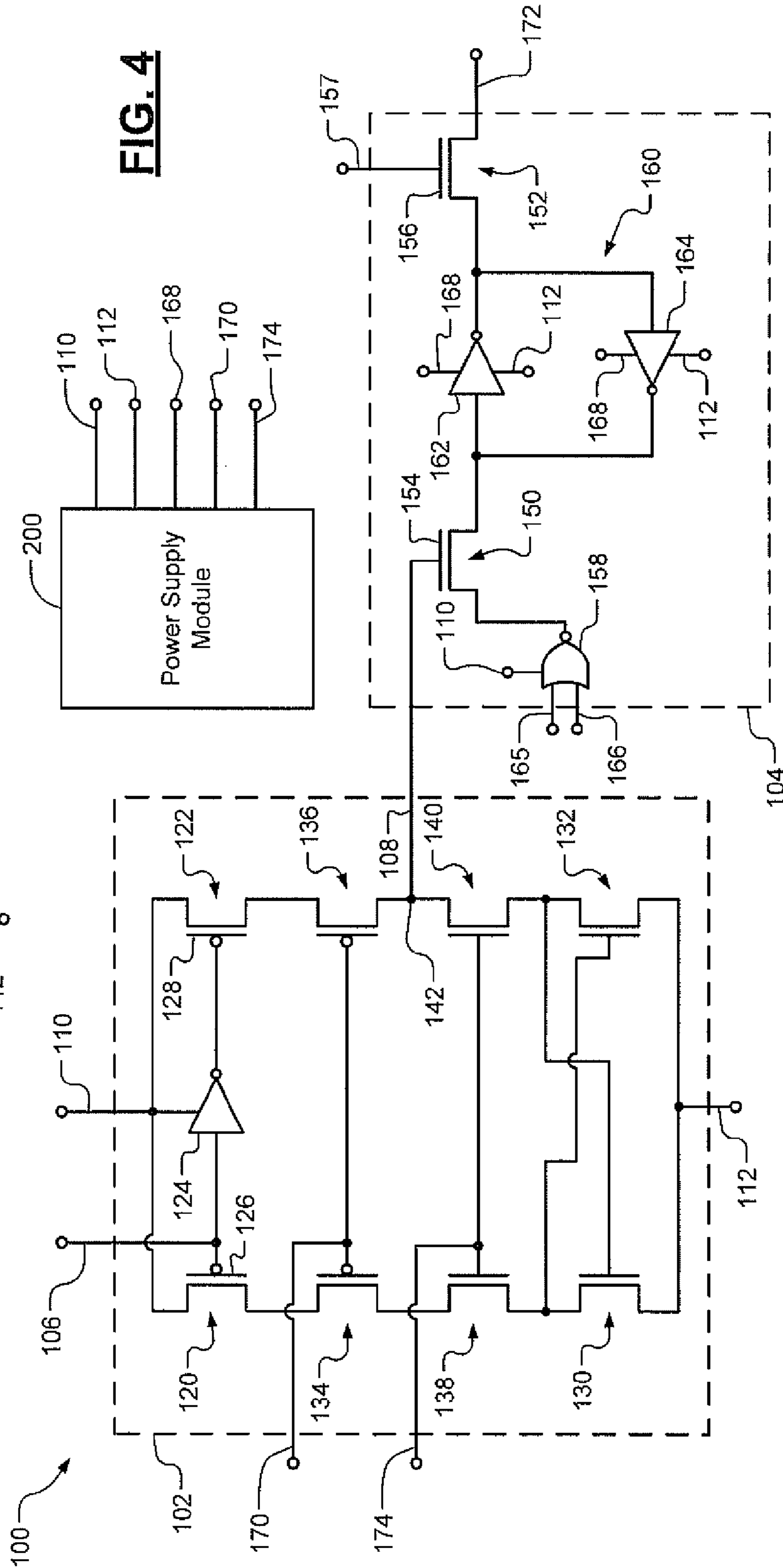


FIG. 4

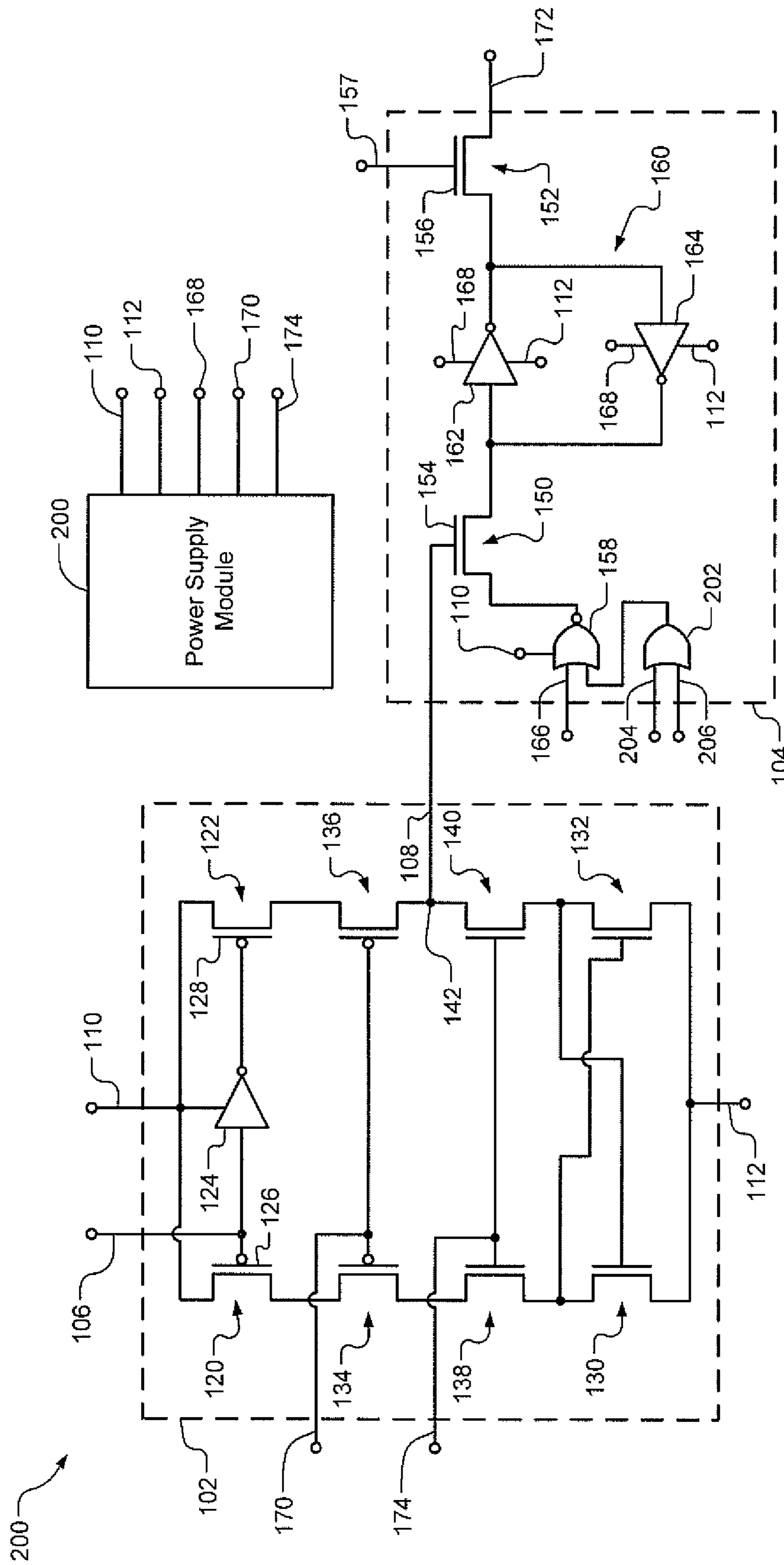


FIG. 5

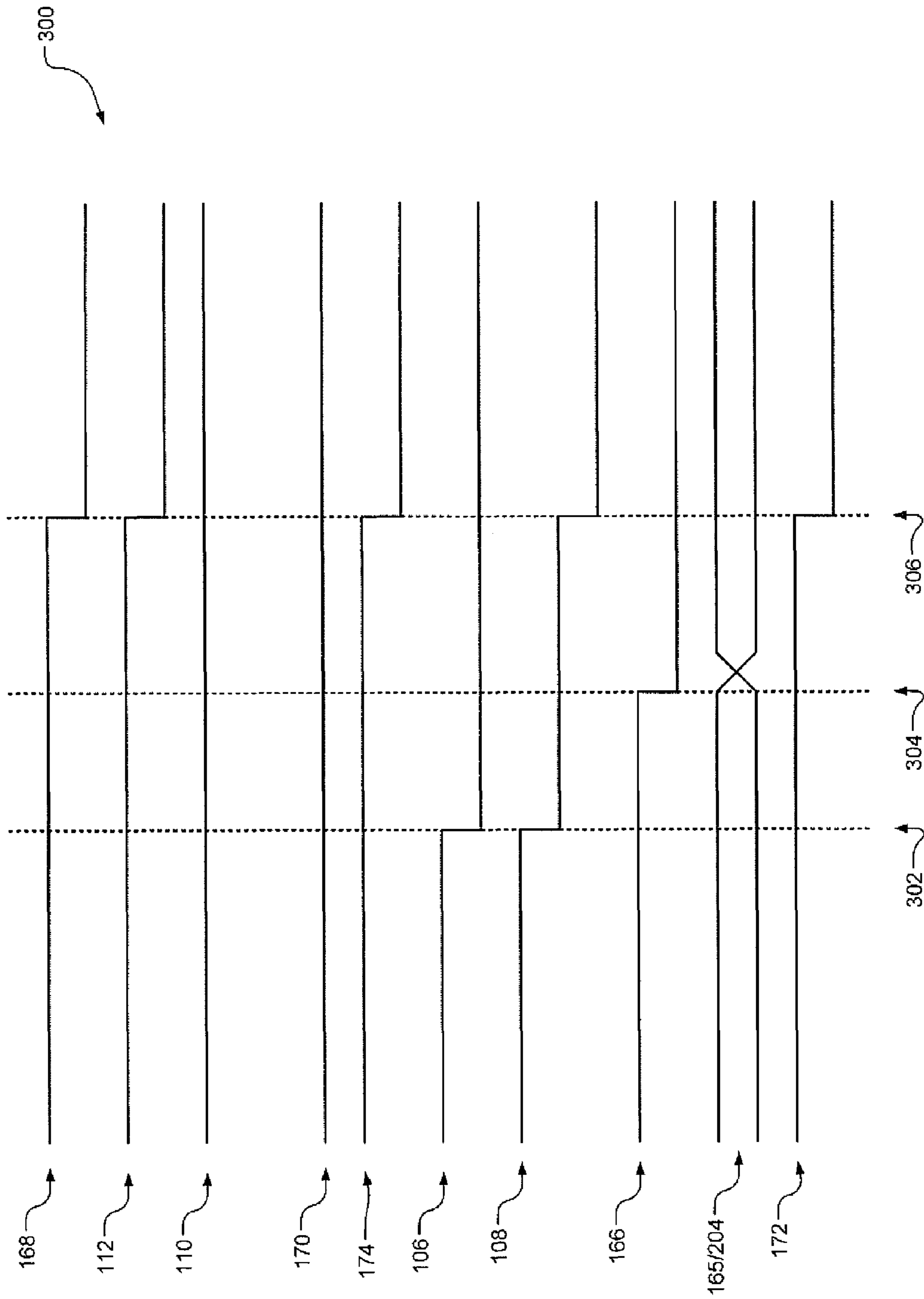


FIG. 6

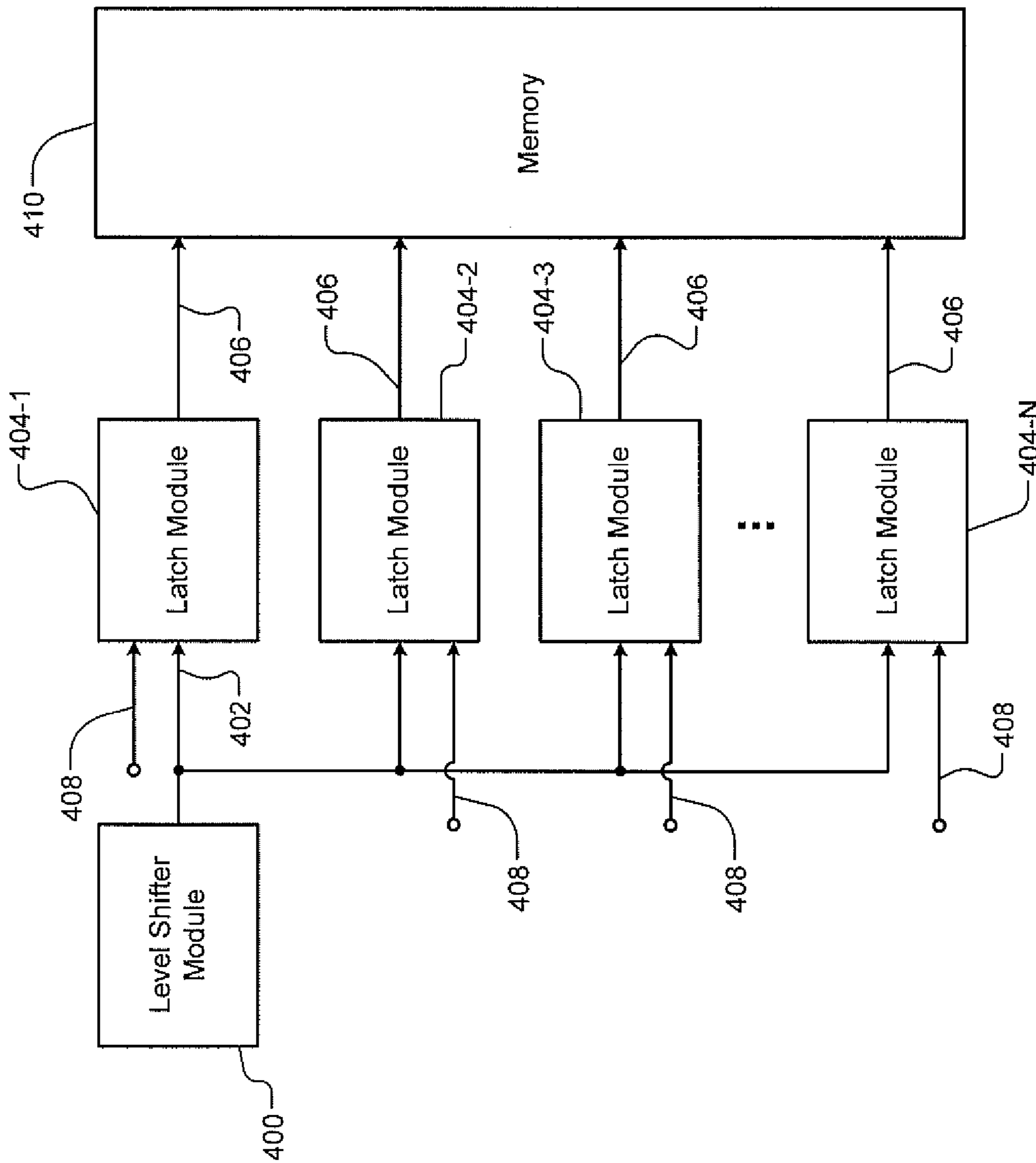


FIG. 7

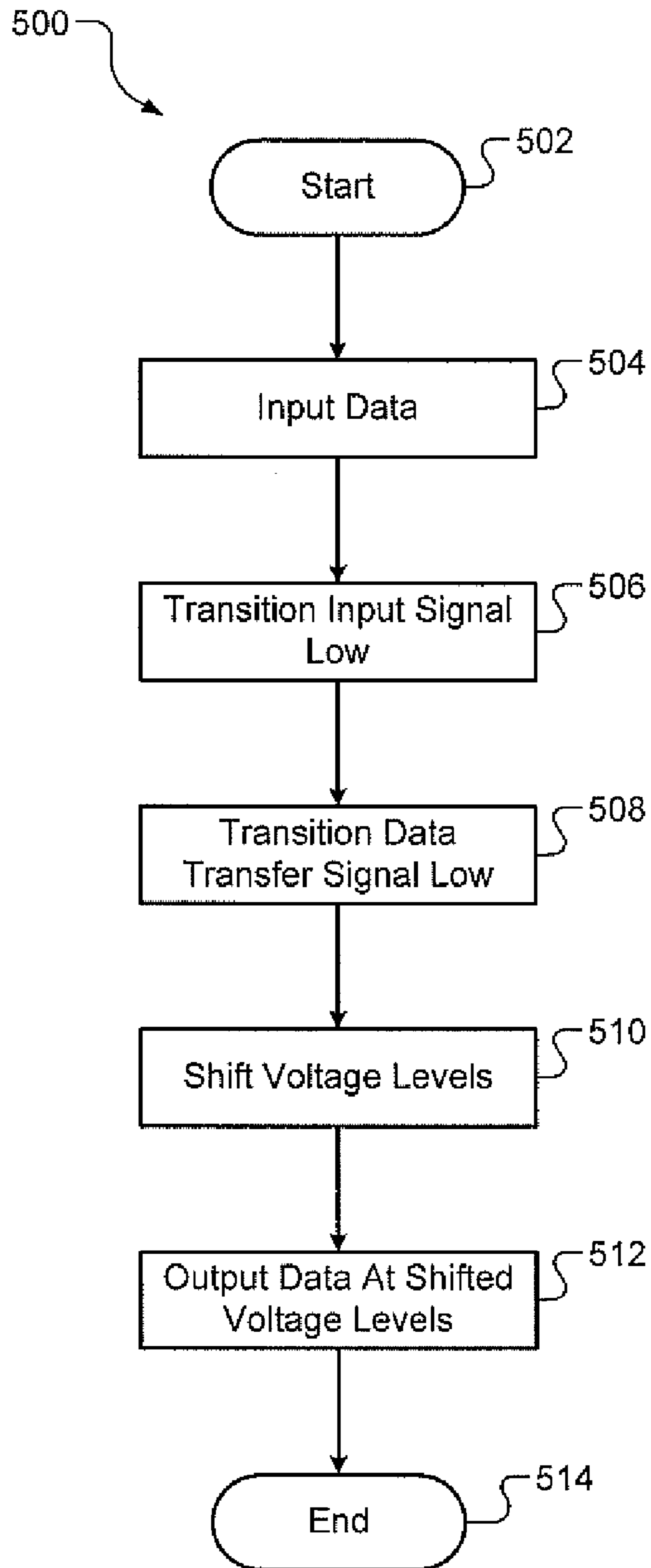


FIG. 8

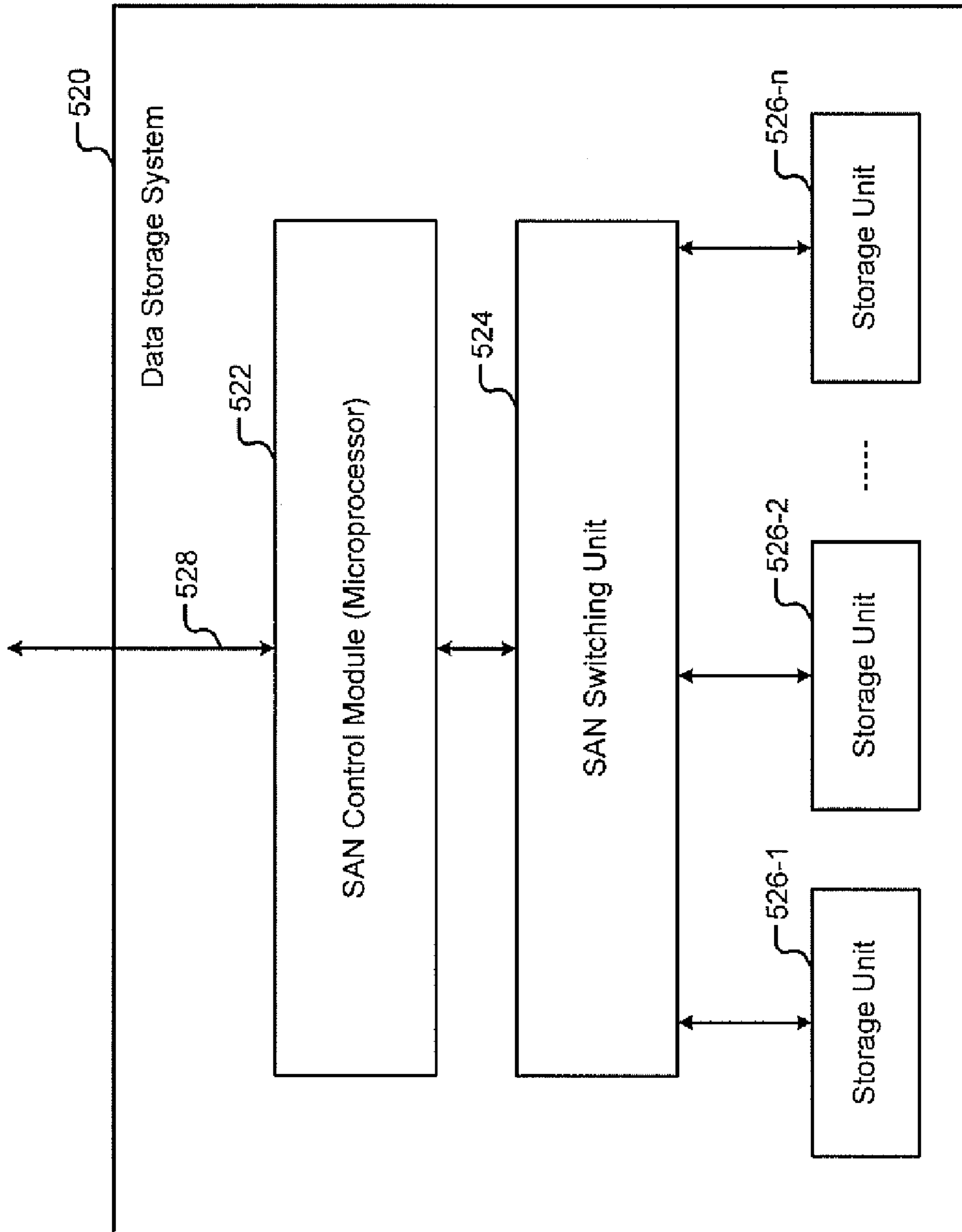


FIG. 9A

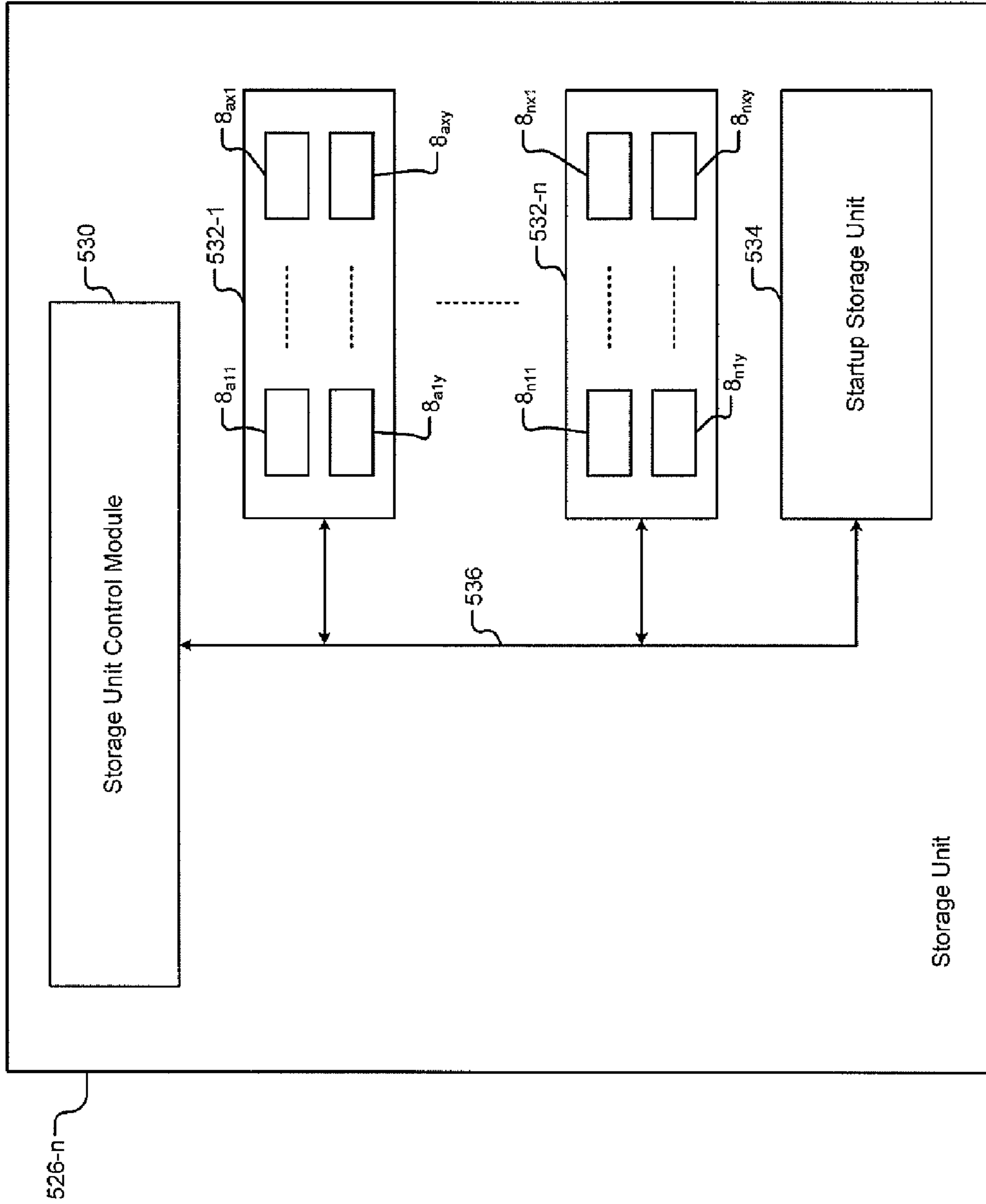


FIG. 9B

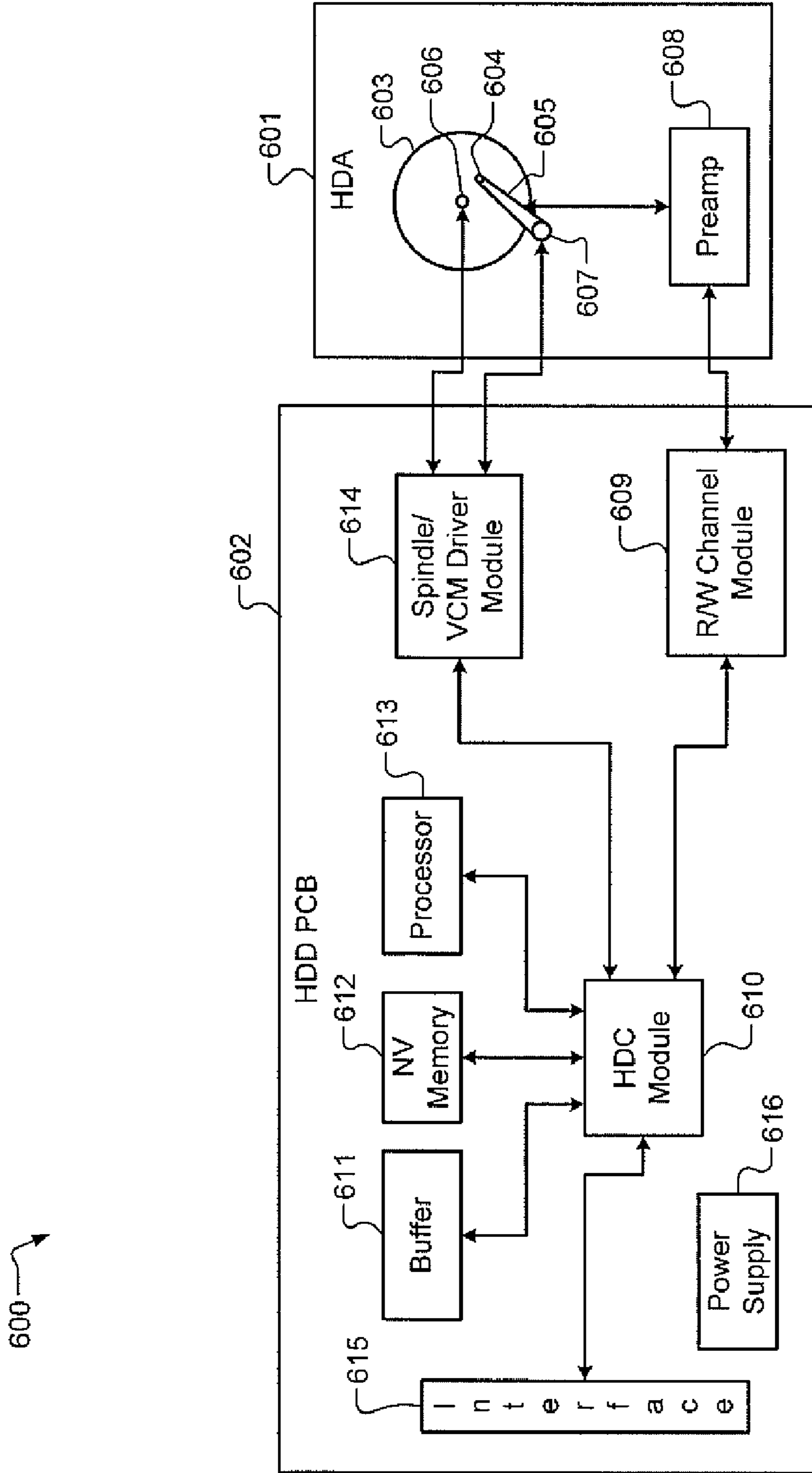


FIG. 9C

618 →

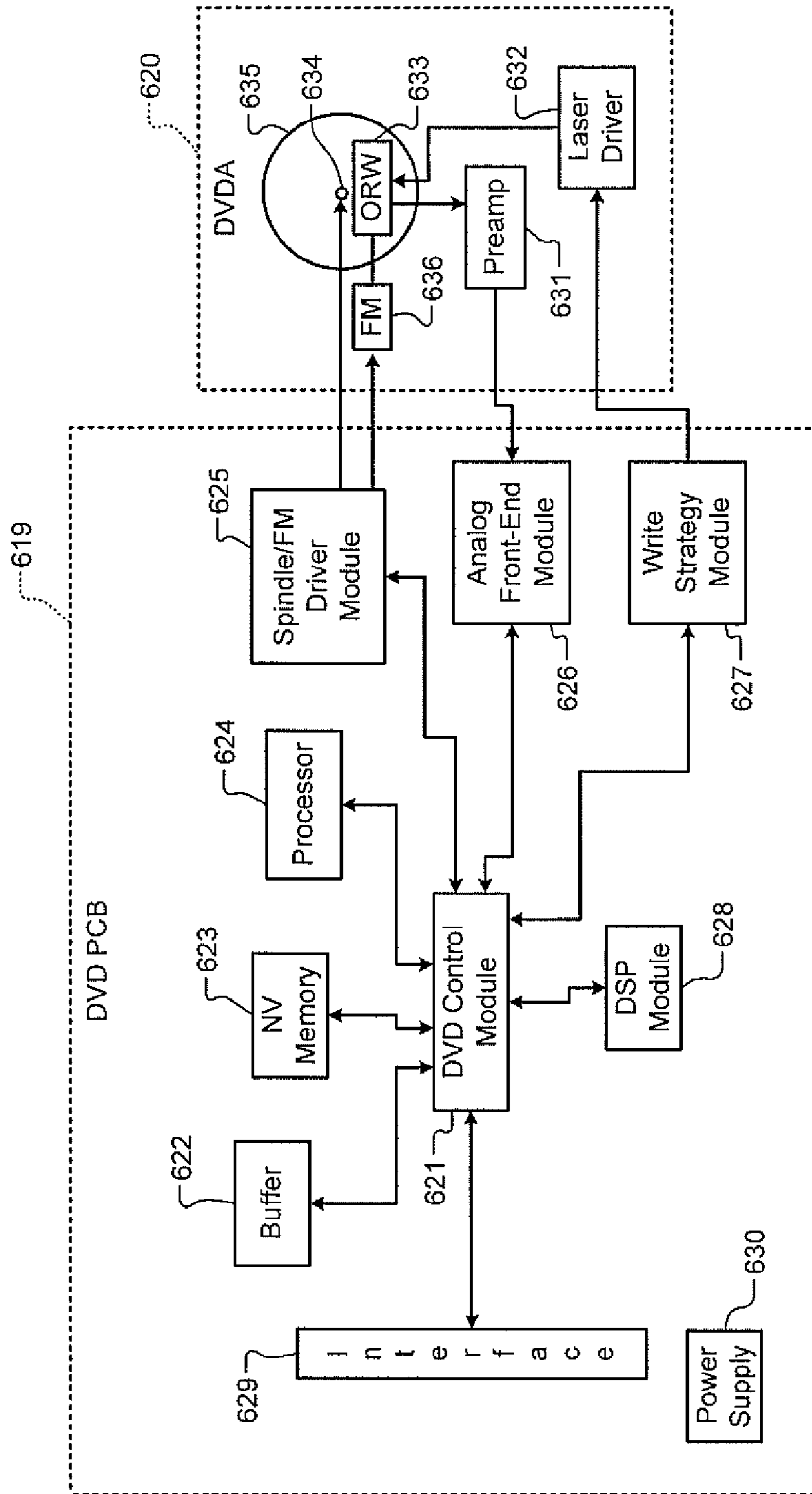


FIG. 9D

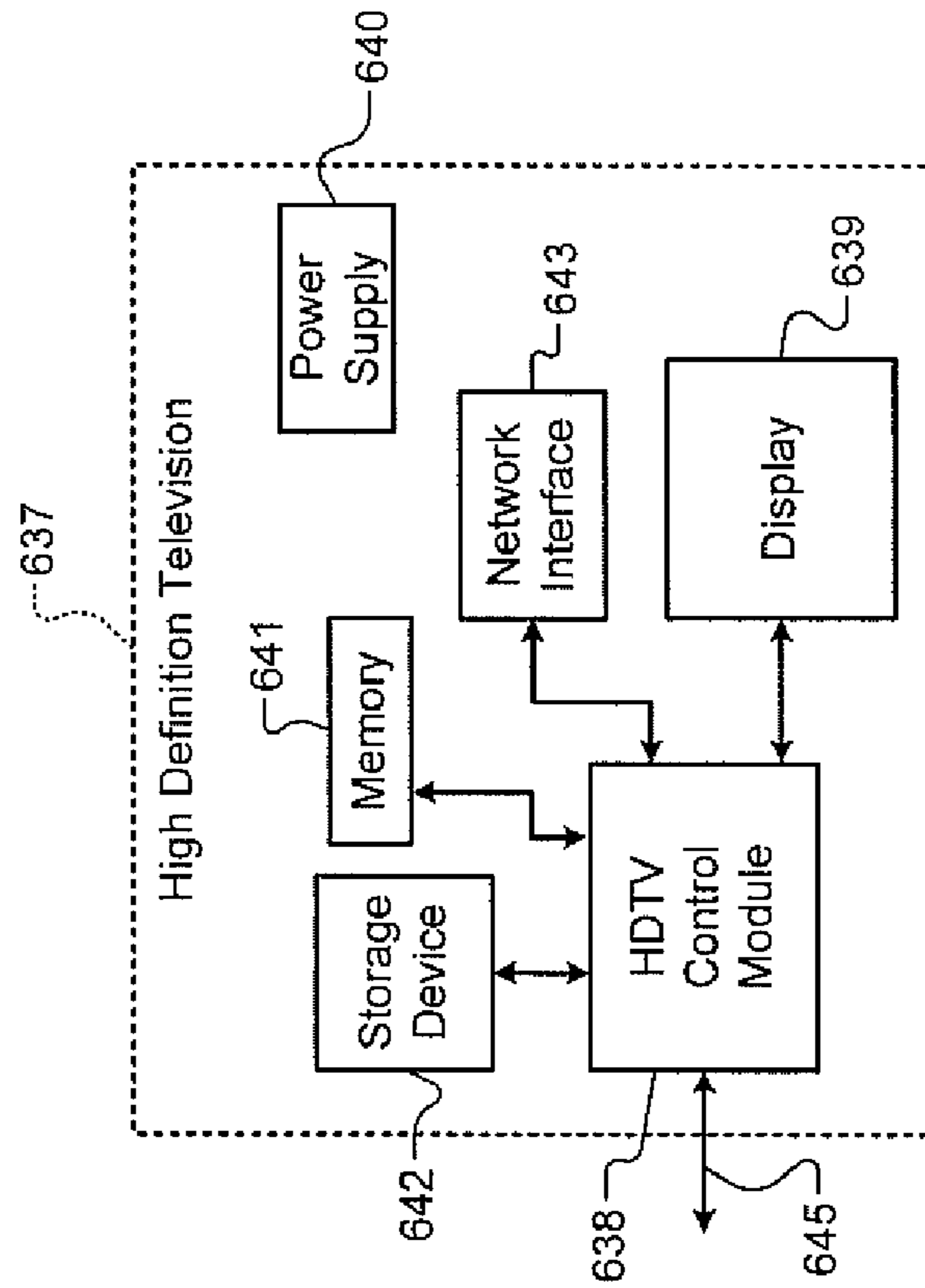
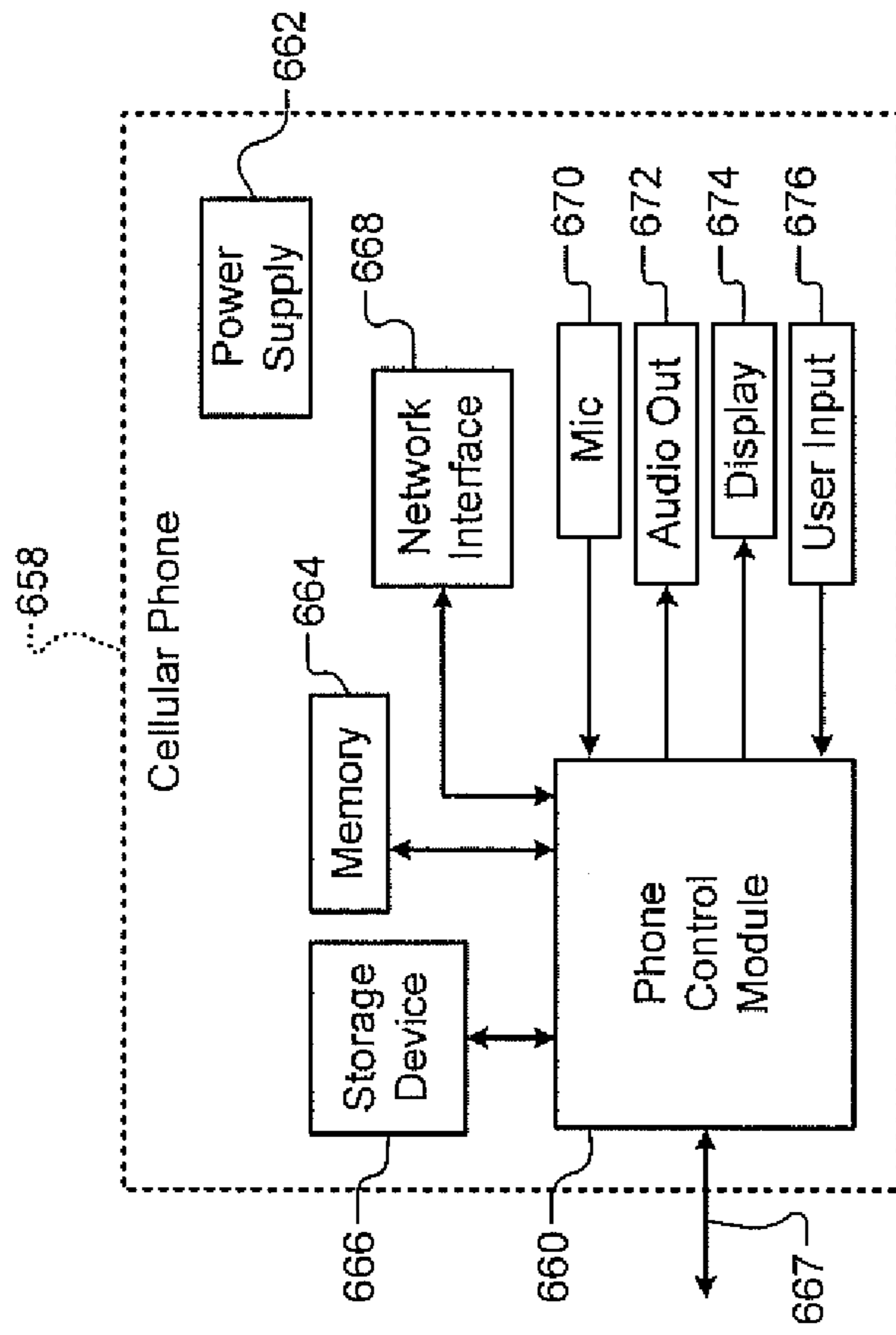


FIG. 9F

FIG. 9E

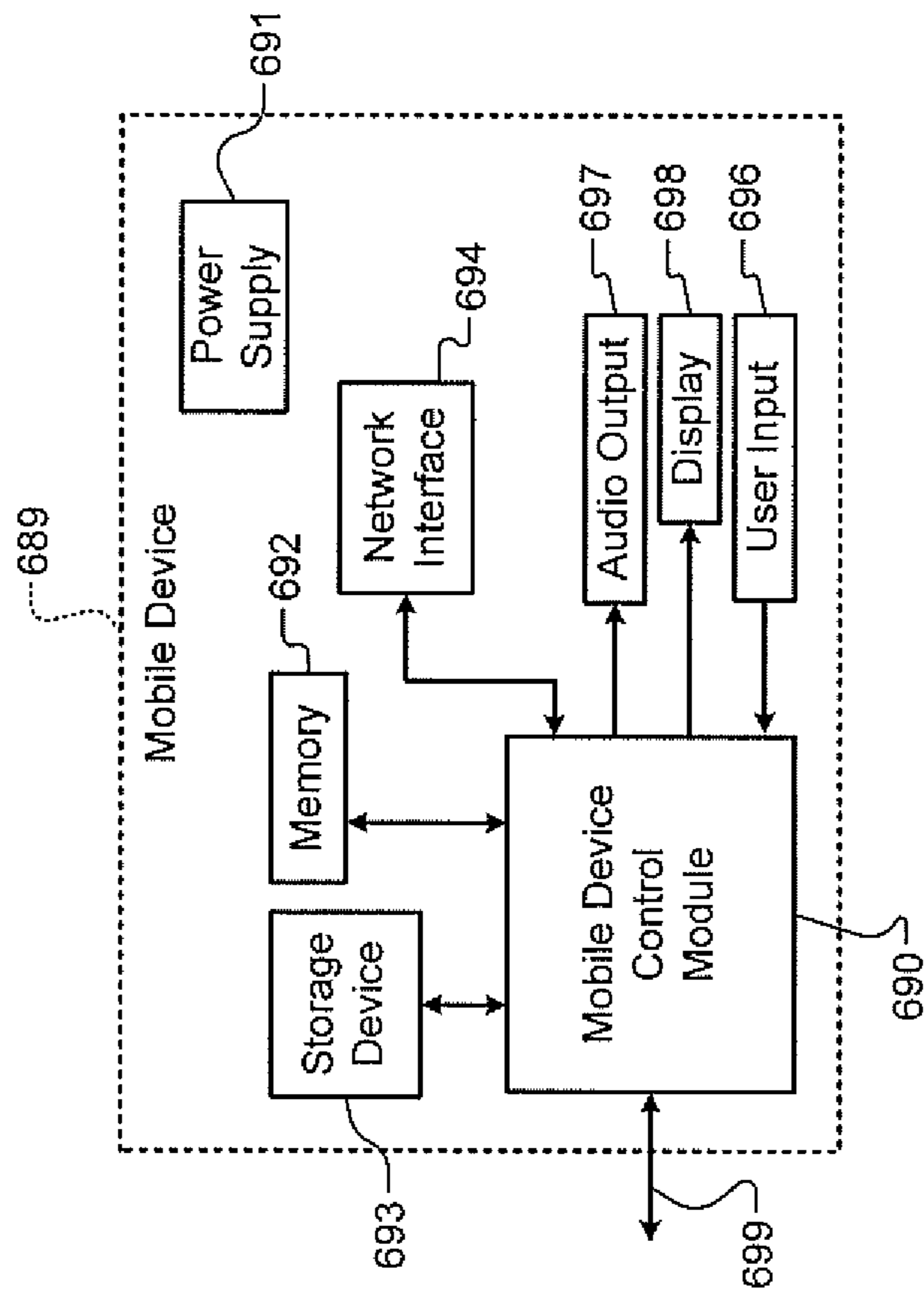


FIG. 9H

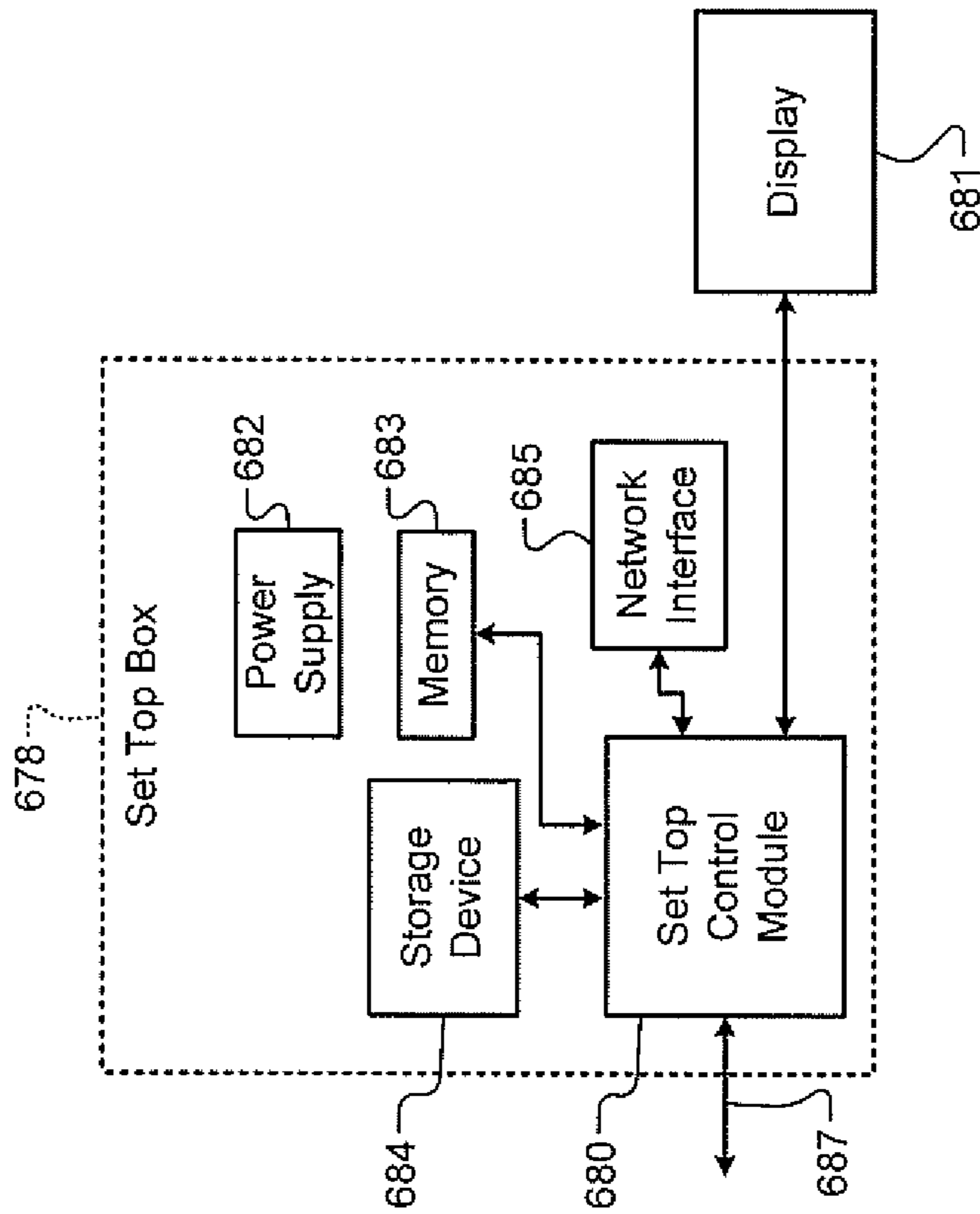


FIG. 9G

POSITIVE AND NEGATIVE VOLTAGE LEVEL SHIFTER CIRCUIT

CROSS-REFERENCE TO RELATED APPLICATIONS

This present disclosure is a continuation of U.S. application Ser. No. 12/250,021 (now U.S. Pat. No. 7,948,810), filed on Oct. 13, 2008, which claims priority under 35 U.S.C. §119(e) to U.S. Provisional Application No. 60/980,017, filed on Oct. 15, 2007.

FIELD

The present disclosure relates to level shifters, and more particularly to a level shifter having a greater output voltage range.

BACKGROUND

The background description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent the work is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

Referring now to FIG. 1, a level shifter **10** is shown. The level shifter **10** receives an input voltage V_{in} and generates an output voltage V_{out} . The level shifter **10** may include first and second NMOS transistors **12** and **14**. A gate **16** of the first NMOS transistor **12** receives the input voltage V_{in} . An inverter **18** is connected between the gate **16** and a gate **20** of the second NMOS transistor **14**. The level shifter **10** includes first and second PMOS transistors **22** and **24** connected in a flip-flop or half latch arrangement. In another configuration, the PMOS transistors **22** and **24** may receive the input voltage V_{in} and the NMOS transistors **12** and **14** may be connected in the flip-flop or half latch arrangement. In other words, the arrangement of the PMOS transistors **22** and **24** and the NMOS transistors **12** and **14** may be reversed.

Referring now to FIG. 2, a level shifter **30** may include first and second protection NMOS transistors **32** and **34** and first and second protection PMOS transistors **36** and **38**. The first and second protection NMOS transistors **32** and **34** communicate with a first protection voltage V_{prot1} . Conversely, the first and second protection PMOS transistors **36** and **38** communicate with a second protection voltage V_{prot2} . The protection voltages V_{prot1} and V_{prot2} bias the protection NMOS transistors **32** and **34** and the protection PMOS transistors **36** and **38**, respectively, to protect the level shifter **30** from excessive electric stress.

Referring now to FIGS. 1 and 2, the level shifters **10** and **30** communicate with input supply voltages V_{ss_in} and V_{dd_in} and output supply voltages V_{ss_out} and V_{dd_out} . Typically, the input supply voltage V_{ss_in} is equivalent to the output supply voltage V_{ss_out} , and the input supply voltage V_{dd_in} is not equivalent to the output supply voltage V_{dd_out} , although those skilled in the art can appreciate that the reverse is true when the positions of the NMOS transistors **12** and **14** and the PMOS transistors **22** and **24** are reversed.

The above described relationships between V_{ss_in} and V_{ss_out} and between V_{dd_in} and V_{ss_out} may limit the operation of the level shifters **10** and **30**. For example, in an NMOS driven level shifter, when V_{ss_out} is greater than V_{dd_in} minus an NMOS threshold voltage V_t , the transistors **12** and **14** remain off regardless of whether a logical 0 or a

logical 1 is applied to an input node. Consequently, the level shifters **10** and **30** will not function properly. Similarly, in a PMOS driven level shifter, when V_{dd_out} is less than V_{ss_in} minus a negative PMOS threshold voltage V_t , the transistors **12** and **14** remain off. As a result, when an NMOS driven level shifter is used, an output low level needs to be equivalent to a logic low level (e.g. 0V, or a logical 0). Similarly, when a PMOS driven level shifter is used, an output high level needs to be equivalent to a logic high level (e.g. 3.3V, or a logical 1).

SUMMARY

A level shifter including a level shifter module configured to i) receive an input signal, wherein the input signal varies between a first level and a second level, ii) receive a first voltage supply signal and a second voltage supply signal, and iii) generate a latch control signal based on the input signal and one of the first voltage supply signal and the second voltage supply signal. The level shifter further includes a latch module configured to i) receive the latch control signal, ii) receive the second voltage supply signal and a third voltage supply signal, and iii) generate an output signal based on the latch control signal and one of the second voltage supply signal and the third voltage supply signal.

Further areas of applicability of the present disclosure will become apparent from the detailed description, the claims and the drawings. It should be understood that the detailed description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

BRIEF DESCRIPTION OF DRAWINGS

The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. 1 illustrates a level shifter according to the prior art;

FIG. 2 illustrates a level shifter including protection transistors according to the prior art;

FIG. 3 is a functional block diagram of a level shifter according to the present disclosure;

FIG. 4 illustrates the level shifter according to the present disclosure in further detail;

FIG. 5 illustrates a second level shifter according to the present disclosure;

FIG. 6 illustrates a signal timing diagram of the level shifter according to the present disclosure;

FIG. 7 illustrates a level shifter including multiple latch modules according to the present disclosure;

FIG. 8 illustrates steps of a method for operating a level shifter according to the present disclosure;

FIG. 9A is a functional block diagram of a data storage system including storage units according to the present disclosure;

FIG. 9B is a functional block diagram of a storage unit of the data storage system of FIG. 9A according to the present disclosure;

FIG. 9C is a functional block diagram of a hard disk drive;

FIG. 9D is a functional block diagram of a DVD drive;

FIG. 9E is a functional block diagram of a high definition television;

FIG. 9F is a functional block diagram of a cellular phone;

FIG. 9G is a functional block diagram of a set top box; and

FIG. 9H is a functional block diagram of a mobile device.

DESCRIPTION

The following description is merely exemplary in nature and is in no way intended to limit the disclosure, its applica-

tion, or uses. For purposes of clarity, the same reference numbers will be used in the drawings to identify similar elements. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A or B or C), using a non-exclusive logical or. It should be understood that steps within a method may be executed in different order without altering the principles of the present disclosure.

As used herein, the term module may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable components that provide the described functionality.

Typically, when an input to an NMOS level shifter varies between, for example only, 0 and 3.3V, an output of the level shifter may vary between 0 and X, where X is greater than an absolute value of a threshold voltage V_t . In other words, a minimum output low level may not be less than 0. Conversely, when an input to a PMOS level shifter varies between, for example only, 0 and 3.3V, an output of the level shifter may vary between X and 3.3V, where X is less than 3.3V minus a threshold voltage V_t . In other words, a maximum output high level may not be greater than 3.3V.

The level shifter circuit of the present disclosure allows for a broader range of output voltages for the same range of input voltages. For example, when the input to the level shifter varies between 0 and 3.3V, the output may vary between, for example only, X and Y, where X is less than a threshold voltage V_t and Y is greater than X plus the threshold voltage V_t . In other implementations, the output may vary between X and Y, where X is less than 3.3V plus a threshold voltage V_t , and Y is greater than X plus the threshold voltage V_t . Accordingly, neither the minimum nor maximum output levels are limited by the minimum input level of 0V and the maximum input level of 3.3V, respectively. For example, with a 3.3V device, the level shifter may shift anywhere between -3.3V and 3.3V for a total range of 6.6V.

Referring now to FIG. 3, a level shifter 100 according to the present disclosure is shown. The level shifter 100 includes a level shifter module 102 and a latch module 104. The level shifter module 102 receives an input signal 106. For example, the input signal 106 may vary between low and high levels (e.g. between 0 and 3.3V). The level shifter module 102 generates a latch control signal 108 based on the input signal 106 and first and second supply signals 110 and 112. For example, when the input signal 106 is high (e.g. 3.3V), the latch control signal 108 is high. When high, the value of the latch control signal 108 may be based on the first supply signal 110. For example only, the first supply signal 110 may be 3.3V (i.e. the same as the high level of the input signal 106).

Conversely, when the input signal 106 is low (e.g. 0V), the latch control signal 108 is low. When low, the value of the latch control signal 108 may be based on the second supply signal 112. The second supply signal 112 may vary between 0V (i.e. the same as the low level of the input signal 106) and -3.3V. Accordingly, the low value of the latch control signal 108 may transition between 0V and -3.3V based on the second supply signal 112.

The latch module 104 generates an output signal 114 based on the latch control signal 108 and a logic input signal 116. The output signal 114 is not limited to a range of 0V to 3.3V. For example, the output signal 114 may transition to a range between -3.3V and 0V.

Referring now to FIG. 4, the level shifter module 102 includes first and second PMOS transistors 120 and 122. A

gate 126 of the first PMOS transistor receives the input signal 106. An inverter 124 is connected between the gate 126 of the first PMOS transistor 120 and a gate 128 of the second PMOS transistor 122. The inverter 124 drives the gate 128 of the second PMOS transistor 122. Each of the PMOS transistors 120 and 122 communicate with the first supply signal 110.

The level shifter module 102 includes first and second NMOS transistors 130 and 132 connected in a flip-flop or half latch arrangement. Each of the transistors 130 and 132 communicate with the second supply signal 112. First and second protection PMOS transistors 134 and 136 and first and second protection NMOS transistors 138 and 140 are connected in a cascade arrangement. Output node 142 generates the latch control signal 108 based on the input signal 106 and the first and second supply signals 110 and 112. For example, the latch control signal 108 may be either high (e.g. 3.3V) or low (e.g. 0 or -3.3V) based on a logic high or low level of the input signal 106.

The latch module 104 includes NMOS transistors 150 and 152. A gate 154 of the NMOS transistor 150 receives the latch control signal 108. Accordingly, the NMOS transistor 150 is on or off based on the latch control signal 108. A gate 156 of the NMOS transistor 152 receives a second latch control signal 157. Accordingly, the NMOS transistor 152 is on or off based on the second latch control signal 157. The NMOS transistor 150 passes an output of a logic gate 158 to a latch 160 that includes inverters 162 and 164 based on the latch control signal 108. Accordingly, the output of the logic gate 158 (e.g. a logical NOR gate) controls an input to the latch 160. The logic gate 158 receives a logic input signal 165 and a data transfer signal 166. A body (i.e. substrate) of each of the NMOS transistors 150 and 152 may be connected to the second supply signal 112 to prevent parasitic PN junctions (not shown).

The inverters 162 and 164 receive the second supply signal 112 and a third supply signal 168 (e.g. at 3.3V). The logic gate 158 may receive the first supply signal 110 as a positive supply signal. Although not shown, each of the logic gate 158 and the inverter 124 may receive a fourth supply signal (such as VSS) 170 as a ground supply signal. For example only, the first supply signal 110 and the fourth supply signal 170 may be equivalent to other logic circuits in an integrated circuit (IC) or system on a chip (SOC) that includes the level shifter 100.

The latch module 104 generates an output signal 172 based on the logic state of the logic input signal 165. For example, the output signal 172 may be based on one of the second supply signal 112 and the third supply signal 168 based on transitions of the logic input signal 165 between low and high states.

Although the second and third supply signals 112 and 168 are given as, for example, 0V and 3.3V, respectively, any voltage can be used as long as the third supply signal 168 is greater than the second supply signal 112 and the latch 160 is functional. For example, the third supply signal 168 may be 0V when the second supply signal 112 is -3.3V. Accordingly, output levels of the level shifter 100 may shift according to the level of the second supply signal 112. In other words, in a high voltage operation mode, the level shifter 100 may shift between 0V and 3.3V. In a low voltage operation mode, the level shifter 100 may shift between -3.3V and 3.3V. Transistors 130 and 132 may receive a protection voltage signal 174.

The level shifter 100 may include a power supply module 200. The power supply module 200 generates the first, second, third, and fourth supply signals 110, 112, 168, and 170, respectively, and the protection voltage signal 174 according to desired operating conditions of the level shifter 100.

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Initially, the third supply signal **168** may be equivalent to the first supply signal **110** (e.g. 3.3V) and the fourth supply signal **170** may be equivalent to the second supply signal **112** (e.g. 0V). To pass data from the input logic signal **165** to the latch **160**, the input signal **106** is set high (e.g. 3.3V). For example, a high level at the input signal **106** may correspond to a command to write data from the input logic signal **165** to memory (not shown). The data transfer signal **166** is set low (e.g. to logical 0). Accordingly, the output of the logic gate **158** will be controlled according to the input logic signal **165**. Further, a polarity of the latch **160** will be set according to the input logic signal **165** passed by the NMOS transistor **150**.

When the value of the input logic signal **165** is set in the latch **160**, the input signal **106** transitions to a low level, applying the value of the second supply signal **112** and therefore turning off the NMOS transistor **150**. The data transfer signal **166** is set high (e.g. to logical 1), transitioning the output of the logic gate **158** to low. For example, since the ground supply signal of the logic gate **158** is the fourth supply signal **170**, the low output level of the logic gate **158** may correspond to the fourth supply signal **170** (e.g. ground or 0V).

With the NMOS transistor **150** turned off, the power supply module **200** may change the voltages of the second and third supply signals **112** and **168**. For example, the power supply module **200** may change the second and third supply signals **112** and **168** from 0V and 3.3V to -3.3V and 0V, respectively (i.e. shift between a high voltage operation mode to a low voltage operation mode). When the second and third supply signals **112** and **168** are changed, the NMOS transistor **152** is turned on (e.g. via transitioning the second latch control signal **157** to a suitable voltage). When the NMOS transistor **152** is on, the selected output voltage of one of the second and third supply signals **112** and **168** is output as the output signal **172**. For example, when the input logic signal **165** is high, the output signal **172** is high (e.g. 0V or 3.3V). When the input logic signal **165** is low, the output signal **172** is low (e.g. -3.3V or 0V).

Shifting various input voltages may protect devices in the level shifter such as the NMOS transistors **130**, **132**, and **150**. For example, if the NMOS transistor **150** is a 3.3V device, a gate voltage of 3.3V with a source/drain voltage of -3.3V may cause undue stress on the NMOS transistor **150**. Accordingly, the output of the logic gate **158** may be shifted to 0V in this situation to prevent a larger voltage across the NMOS transistor **150**. Similarly, the protection voltage signal **174** received at the NMOS transistors **138** and **140** may be changed to the level of the fourth supply signal **170** (e.g. 0V or ground) when the second supply signal **112** is changed to a lower level such as -3.3V. Accordingly, second and third supply signals **112** and **168** may have any voltage value as long as their difference does not introduce excessive stress on the transistors, their difference is large enough to keep the latch **160** set, and the NMOS transistor **150** remains off during level shifting.

In certain operating conditions of the level shifter **100** shown in FIG. 4, the NMOS transistor **150** may inadvertently be turned on. For example, when the output of the logic gate **158** is 0V and the second supply signal **112** is greater than 0V plus an NMOS threshold voltage V_t , the NMOS transistor **150** may turn on. Similarly, when the output of the logic gate **158** is 0V and the second supply signal **112** is greater than 0V plus a PN diode voltage, a parasitic PN junction diode between a body and a source of the NMOS transistor **150** may turn on. Accordingly, the second supply signal **112** may still be limited.

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Referring now to FIG. 5, a level shifter **200** includes the logic gate **158** and a logic gate **202**. The logic gate **202** receives an inverted input logic signal **204** and a logic control signal **206**. The logic gate **158** receives an output of the logic gate **202** and the data transfer signal **166**. When the second supply signal **112** is less than or equal to 0V (i.e. not positive), the logic control signal **206** is low (i.e. logical 0) and the level shifter **200** operates analogously to the level shifter **100** shown in FIG. 4.

When the second supply signal **112** is greater than 0V (i.e. positive), the logic control signal **206** is high (i.e. logical 1) and the data transfer signal **166** is low (i.e. logical 0). Accordingly, in this circumstance, the output of the logic gate **158** is forced high (i.e. to 3.3V), thereby ensuring that the NMOS transistor **150** remains off even when the second supply signal **112** is positive. In other words, the output of the logic gate **158** as shown in FIG. 5 may be low (e.g. 0V) or high (e.g. 3.3V) based on whether the second supply signal **112** is negative or positive.

Referring now to FIG. 6, a timing diagram **300** for the various signals described in FIGS. 3-5 is shown. The output signal **172** follows one of the input logic signal **165** and the inverted input logic signal **204** for FIGS. 4 and 5, respectively. When the input signal **106** is high, none of the values of the supply signals are changed and the value of the input logic signal **165** (or the inverted input logic signal **204**) is set in the latch **160**. When the input signal **106** is low, the latch control signal **108** transitions low to turn off the NMOS transistor **150** as indicated at **302**. At **304**, the data transfer signal **166** transitions low to ensure that the NMOS transistor **150** remains off during level shifting.

At **306**, the second supply signal **112** is shifted from 0V to -3.3V. The third supply signal **168** is shifted from 3.3V to 0V. The protection voltage signal **174** may be shifted from 3.3V to 0V to reduce stress on certain devices. The first supply signal **110** and the fourth supply signal **170** remain high (e.g. 3.3V) and low (e.g. ground or 0V), respectively.

Referring now to FIG. 7, a level shifter module **400** may provide a latch control signal **402** to multiple latch modules **404-1**, **404-2**, **404-3**, . . . , and **404-N** (referred to collectively as latch modules **404**). Each of the latch modules **404** may generate a different output signal **406** based on respective input signals **408**. The latch modules **404** may input data based on the output signals **406** according to the level shifting operation as described in FIGS. 3-6. For example, each of the latch modules **404** may input data to an input line of memory **410** (which may include, for example only, a memory IC). Alternatively, a single one of the latch modules **404** may be implemented with multiplexing to input data to multiple lines of the memory **410**. For example only, the memory **410** may include nonvolatile memory.

Referring now to FIG. 8, a method **500** for operating a level shifter having a level shifter module **102** and a latch module **104** according to the present disclosure begins in step **502**. In step **504**, data is input to the latch module **104** with supply voltages at a first level. In step **506**, an input signal to the level shifter module **102** transitions low. In step **508**, a data transfer signal input to the latch module **104** transitions low to set the data in the latch module **104**. In step **510**, levels of supply signals to the level shifter module **102** and the latch module **104** are shifted between high and low operation voltages. In step **512**, the data is output from the latch module **104** according to the new operation voltages. The method **500** ends in step **514**.

Referring now to FIGS. 9A-9H, various exemplary implementations incorporating the teachings of the present disclosure are shown.

Referring now to FIGS. 9A and 9B, the teachings of the present disclosure can be extended to storage products including data storage systems and solid-state disks. The architecture and configuration of the data storage system shown in FIGS. 9A and 9B are exemplary. Other architectures and device configurations are contemplated.

In FIG. 9A, for example only, a data storage system 520 may comprise a storage area network (SAN) control module 522, a SAN switching unit 524, and storage units 526-1, 526-2, . . . , and 526-n (collectively storage units 526). The SAN control module 522 may comprise a control unit that interfaces the data storage system 520 to one or more external devices (not shown) through an input/output (I/O) bus 528. For example, the control unit may include a processor, a microprocessor, an ASIC, a state machine, etc. For example, the external devices may include a host, a server, etc. The I/O bus 528 may comprise a bus that provides high speed and wide bandwidth for data transmission. For example, the I/O bus 528 may include fiber-channels, Ethernet, etc. For example only, the transmission speed of the I/O bus 528 may be faster than 10 gigabits per second (10 Gb/s).

Additionally, the SAN control module 522 may control the SAN switching unit 524. For example only, the SAN switching unit 524 may include a plurality of switches. Each of the switches may interface with one of the storage units 526 and may be controlled via control signals from the SAN control module 522. The storage units 526 may store information that includes audio data, video data, and/or any other types of data in a digital format.

In FIG. 9B, for example only, one of the storage units 526 (e.g., the storage unit 526-n) may comprise a storage unit control module 530, solid-state drives (SSDs) 532-1, . . . , and 532-n (collectively SSDs 532), a startup storage unit 534, and a bus 536. An SSD may refer to a data storage device that uses solid-state memory to store data, such as a flash memory drive. Each of the SSDs 532 may comprise one or more of the memory 410 of FIG. 7, shown as memory ICs 410a11-410nxy. The variables a and n refer to the SSD. The variables x and y refer to a memory IC within a SSD. The variable a may be equal to 1 and the variables n, x, and y may be integers greater than 1. Additionally, each of the SSDs 532 may comprise a memory controller (not shown) that controls the one or more of the memory ICs 410a11-410nxy. The startup storage unit 534 may include code for operating the storage unit control module 530. Using the code, the storage unit control module 530 may control the SSDs 532 via the bus 536.

Referring now to FIG. 9C, the teachings of the disclosure can be implemented in memory 612 of a hard disk drive (HDD) 600. The HDD 600 includes a hard disk assembly (HDA) 601 and an HDD printed circuit board (PCB) 602. The HDA 601 may include a magnetic medium 603, such as one or more platters that store data, and a read/write device 604. The read/write device 604 may be arranged on an actuator arm 605 and may read and write data on the magnetic medium 603. Additionally, the HDA 601 includes a spindle motor 606 that rotates the magnetic medium 603 and a voice-coil motor (VCM) 607 that actuates the actuator arm 605. A preamplifier device 608 amplifies signals generated by the read/write device 604 during read operations and provides signals to the read/write device 604 during write operations.

The HDD PCB 602 includes a read/write channel module (hereinafter, "read channel") 609, a hard disk controller (HDC) module 610, a buffer 611, memory 612, a processor 613, and a spindle/VCM driver module 614. The read channel 609 processes data received from and transmitted to the preamplifier device 608. The HDC module 610 controls components of the HDA 601 and communicates with an external

device (not shown) via an I/O interface 615. The external device may include a computer, a multimedia device, a mobile computing device, etc. The I/O interface 615 may include wireline and/or wireless communication links.

The HDC module 610 may receive data from the HDA 601, the read channel 609, the buffer 611, memory 612, the processor 613, the spindle/VCM driver module 614, and/or the I/O interface 615. The processor 613 may process the data, including encoding, decoding, filtering, and/or formatting. The processed data may be output to the HDA 601, the read channel 609, the buffer 611, nonvolatile memory 612, the processor 613, the spindle/VCM driver module 614, and/or the I/O interface 615.

The HDC module 610 may use the buffer 611 and/or nonvolatile memory 612 to store data related to the control and operation of the HDD 600. The buffer 611 may include DRAM, SDRAM, etc. Memory 612 may include RAM or any suitable type of semiconductor or solid-state memory, such as flash memory (including NAND and NOR flash memory), phase change memory, magnetic RAM, and multi-state memory, in which each memory cell has more than two states. The spindle/VCM driver module 614 controls the spindle motor 606 and the VCM 607. The HDD PCB 602 includes a power supply 616 that provides power to the components of the HDD 600.

Referring now to FIG. 9D, the teachings of the disclosure can be implemented in memory 623 of a DVD drive 618 or of a CD drive (not shown). The DVD drive 618 includes a DVD PCB 619 and a DVD assembly (DVDA) 620. The DVD PCB 619 includes a DVD control module 621, a buffer 622, memory 623, a processor 624, a spindle/FM (feed motor) driver module 625, an analog front-end module 626, a write strategy module 627, and a DSP module 628.

The DVD control module 621 controls components of the DVDA 620 and communicates with an external device (not shown) via an I/O interface 629. The external device may include a computer, a multimedia device, a mobile computing device, etc. The I/O interface 629 may include wireline and/or wireless communication links.

The DVD control module 621 may receive data from the buffer 622, memory 623, the processor 624, the spindle/FM driver module 625, the analog front-end module 626, the write strategy module 627, the DSP module 628, and/or the I/O interface 629. The processor 624 may process the data, including encoding, decoding, filtering, and/or formatting. The DSP module 628 performs signal processing, such as video and/or audio coding/decoding. The processed data may be output to the buffer 622, memory 623, the processor 624, the spindle/FM driver module 625, the analog front-end module 626, the write strategy module 627, the DSP module 628, and/or the I/O interface 629.

The DVD control module 621 may use the buffer 622 and/or memory 623 to store data related to the control and operation of the DVD drive 618. The buffer 622 may include DRAM, SDRAM, etc. Memory 623 may include RAM or any suitable type of semiconductor or solid-state memory, such as flash memory (including NAND and NOR flash memory), phase change memory, magnetic RAM, and multi-state memory, in which each memory cell has more than two states. The DVD PCB 619 includes a power supply 630 that provides power to the components of the DVD drive 618.

The DVDA 620 may include a preamplifier device 631, a laser driver 632, and an optical device 633, which may be an optical read/write (ORW) device or an optical read-only (OR) device. A spindle motor 634 rotates an optical storage medium 635, and a feed motor 636 actuates the optical device 633 relative to the optical storage medium 635.

When reading data from the optical storage medium **635**, the laser driver provides a read power to the optical device **633**. The optical device **633** detects data from the optical storage medium **635**, and transmits the data to the preamplifier device **631**. The analog front-end module **626** receives data from the preamplifier device **631** and performs such functions as filtering and A/D conversion. To write to the optical storage medium **635**, the write strategy module **627** transmits power level and timing data to the laser driver **632**. The laser driver **632** controls the optical device **633** to write data to the optical storage medium **635**.

Referring now to FIG. 9E, the teachings of the disclosure can be implemented in memory **641** of a high definition television (HDTV) **637**. The HDTV **637** includes an HDTV control module **638**, a display **639**, a power supply **640**, memory **641**, a storage device **642**, a network interface **643**, and an external interface **645**. If the network interface **643** includes a wireless local area network interface, an antenna (not shown) may be included.

The HDTV **637** can receive input signals from the network interface **643** and/or the external interface **645**, which can send and receive data via cable, broadband Internet, and/or satellite. The HDTV control module **638** may process the input signals, including encoding, decoding, filtering, and/or formatting, and generate output signals. The output signals may be communicated to one or more of the display **639**, memory **641**, the storage device **642**, the network interface **643**, and the external interface **645**.

Memory **641** may include random access memory (RAM) and/or nonvolatile memory. Nonvolatile memory may include any suitable type of semiconductor or solid-state memory, such as flash memory (including NAND and NOR flash memory), phase change memory, magnetic RAM, and multi-state memory, in which each memory cell has more than two states. The storage device **642** may include an optical storage drive, such as a DVD drive, and/or a hard disk drive (HDD). The HDTV control module **638** communicates externally via the network interface **643** and/or the external interface **645**. The power supply **640** provides power to the components of the HDTV **637**.

Referring now to FIG. 9F, the teachings of the disclosure can be implemented in memory **664** of a cellular phone **658**. The cellular phone **658** includes a phone control module **660**, a power supply **662**, memory **664**, a storage device **666**, and a cellular network interface **667**. The cellular phone **658** may include a network interface **668**, a microphone **670**, an audio output **672** such as a speaker and/or output jack, a display **674**, and a user input device **676** such as a keypad and/or pointing device. If the network interface **668** includes a wireless local area network interface, an antenna (not shown) may be included.

The phone control module **660** may receive input signals from the cellular network interface **667**, the network interface **668**, the microphone **670**, and/or the user input device **676**. The phone control module **660** may process signals, including encoding, decoding, filtering, and/or formatting, and generate output signals. The output signals may be communicated to one or more of memory **664**, the storage device **666**, the cellular network interface **667**, the network interface **668**, and the audio output **672**.

Memory **664** may include random access memory (RAM) and/or nonvolatile memory. Nonvolatile memory may include any suitable type of semiconductor or solid-state memory, such as flash memory (including NAND and NOR flash memory), phase change memory, magnetic RAM, and multi-state memory, in which each memory cell has more than two states. The storage device **666** may include an opti-

cal storage drive, such as a DVD drive, and/or a hard disk drive (HDD). The power supply **662** provides power to the components of the cellular phone **658**.

Referring now to FIG. 9G, the teachings of the disclosure can be implemented in memory **683** of a set top box **678**. The set top box **678** includes a set top control module **680**, a display **681**, a power supply **682**, memory **683**, a storage device **684**, and a network interface **685**. If the network interface **685** includes a wireless local area network interface, an antenna (not shown) may be included.

The set top control module **680** may receive input signals from the network interface **685** and an external interface **687**, which can send and receive data via cable, broadband Internet, and/or satellite. The set top control module **680** may process signals, including encoding, decoding, filtering, and/or formatting, and generate output signals. The output signals may include audio and/or video signals in standard and/or high definition formats. The output signals may be communicated to the network interface **685** and/or to the display **681**. The display **681** may include a television, a projector, and/or a monitor.

The power supply **682** provides power to the components of the set top box **678**. Memory **683** may include random access memory (RAM) and/or nonvolatile memory. Nonvolatile memory may include any suitable type of semiconductor or solid-state memory, such as flash memory (including NAND and NOR flash memory), phase change memory, magnetic RAM, and multi-state memory, in which each memory cell has more than two states. The storage device **684** may include an optical storage drive, such as a DVD drive, and/or a hard disk drive (HDD).

Referring now to FIG. 9H, the teachings of the disclosure can be implemented in memory **692** of a mobile device **689**. The mobile device **689** may include a mobile device control module **690**, a power supply **691**, memory **692**, a storage device **693**, a network interface **694**, and an external interface **699**. If the network interface **694** includes a wireless local area network interface, an antenna (not shown) may be included.

The mobile device control module **690** may receive input signals from the network interface **694** and/or the external interface **699**. The external interface **699** may include USB, infrared, and/or Ethernet. The input signals may include compressed audio and/or video, and may be compliant with the MP3 format. Additionally, the mobile device control module **690** may receive input from a user input **696** such as a keypad, touchpad, or individual buttons. The mobile device control module **690** may process input signals, including encoding, decoding, filtering, and/or formatting, and generate output signals.

The mobile device control module **690** may output audio signals to an audio output **697** and video signals to a display **698**. The audio output **697** may include a speaker and/or an output jack. The display **698** may present a graphical user interface, which may include menus, icons, etc. The power supply **691** provides power to the components of the mobile device **689**. Memory **692** may include random access memory (RAM) and/or nonvolatile memory.

Nonvolatile memory may include any suitable type of semiconductor or solid-state memory, such as flash memory (including NAND and NOR flash memory), phase change memory, magnetic RAM, and multi-state memory, in which each memory cell has more than two states. The storage device **693** may include an optical storage drive, such as a DVD drive, and/or a hard disk drive (HDD). The mobile

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device may include a personal digital assistant, a media player, a laptop computer, a gaming console, or other mobile computing device.

Those skilled in the art can now appreciate from the foregoing description that the broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited since other modifications will become apparent upon a study of the drawings, the specification, and the following claims.

What is claimed is:

1. A level shifter, comprising:
 - a level shifter module configured to i) receive an input signal, wherein the input signal varies between a first level and a second level, ii) receive a first voltage supply signal and a second voltage supply signal, and iii) generate a latch control signal based on the input signal and one of the first voltage supply signal and the second voltage supply signal, wherein
 - when the input signal is at the first level, the latch control signal is based on the input signal and the first voltage supply signal, and
 - when the input signal is at the second level, the latch control signal is based on the input signal and the second voltage supply signal; and
 - a latch module configured to i) receive the latch control signal, ii) receive the second voltage supply signal and a third voltage supply signal, and iii) generate an output signal based on the latch control signal and one of the second voltage supply signal and the third voltage supply signal, wherein
 - in a first mode, the second voltage supply signal has a first voltage and the third voltage supply signal has a second voltage, and
 - in a second mode, the second voltage supply signal has a third voltage and the third voltage supply signal has a fourth voltage,
 - wherein the second voltage is greater than the first voltage, and the fourth voltage is greater than the third voltage.
2. The level shifter of claim 1, wherein the third voltage is greater than the first voltage, and the fourth voltage is greater than the second voltage.
3. The level shifter of claim 1, wherein in the first mode i) the first voltage supply signal has the second voltage equivalent to the third voltage supply signal, and ii) the second voltage is greater than the first voltage.
4. The level shifter of claim 1, wherein in the second mode i) the first voltage supply signal has the second voltage, ii) the second voltage is greater than the fourth voltage associated with the third voltage supply signal, and iii) the fourth voltage is greater than the third voltage associated with the second voltage supply signal.
5. The level shifter of claim 1, wherein the first voltage is equal to the fourth voltage.
6. The level shifter of claim 1, further comprising a power supply module that selects between the first mode and the second mode based on the input signal.
7. The level shifter of claim 1, wherein the output signal is further based on an input logic signal that varies between a first logic state and a second logic state.

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8. The level shifter of claim 7, wherein the output signal is based on i) the second voltage supply signal when the input logic signal has the first logic state and ii) the third voltage supply signal when the input logic signal has the second logic state.

9. A method of operating a level shifter, the method comprising:

using a level shifter,

receiving an input signal, wherein the input signal varies between a first level and a second level,

generating a latch control signal based on the input signal and one of a first voltage supply signal and a second voltage supply signal, wherein

when the input signal is at the first level, the latch control signal is based on the input signal and the first voltage supply signal, and

when the input signal is at the second level, the latch control signal is based on the input signal and the second voltage supply signal; and

generating an output signal based on the latch control signal and one of the second voltage supply signal and a third voltage supply signal, wherein

in a first mode, the second voltage supply signal has a first voltage and the third voltage supply signal has a second voltage, and

in a second mode, the second voltage supply signal has a third voltage and the third voltage supply signal has a fourth voltage,

wherein the second voltage is greater than the first voltage, and the fourth voltage is greater than the third voltage.

10. The method of claim 9, wherein the third voltage is greater than the first voltage, and the fourth voltage is greater than the second voltage.

11. The method of claim 9, wherein in the first mode i) the first voltage supply signal has the second voltage equivalent to the third voltage supply signal, and ii) the second voltage is greater than the first voltage.

12. The method of claim 9, wherein in the second mode i) the first voltage supply signal has the second voltage, ii) the second voltage is greater than the fourth voltage associated with the third voltage supply signal, and iii) the fourth voltage is greater than the third voltage associated with the second voltage supply signal.

13. The method of claim 9, wherein the first voltage is equal to the fourth voltage.

14. The method of claim 9, further comprising selecting between the first mode and the second mode based on the input signal.

15. The method of claim 9, wherein the output signal is further based on an input logic signal that varies between a first logic state and a second logic state.

16. The method of claim 15, wherein the output signal is based on i) the second voltage supply signal when the input logic signal has the first logic state and ii) the third voltage supply signal when the input logic signal has the second logic state.